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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 144.

B. T. GALLOWAY, *Chief of Bureau.*

APPLE BLOTCH.

A SERIOUS DISEASE OF SOUTHERN ORCHARDS.

BY

W. M. SCOTT, PATHOLOGIST,

AND

JAMES B. RORER, ASSISTANT PATHOLOGIST,
FRUIT DISEASE INVESTIGATIONS.

ISSUED MARCH 6, 1909.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

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APPLE BLOTCH ON FRUITS, TWIGS, AND LEAF.

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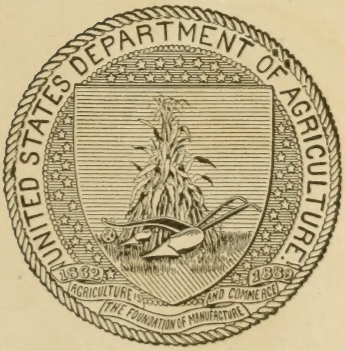

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of Chief of Bureau,
Washington, D. C., November 25, 1908.

Sir: I have the honor to transmit herewith a paper entitled "Apple Blotch, a Serious Disease of Southern Orchards," by Messrs. W. M. Scott, Pathologist, and James B. Rorer, Assistant Pathologist, of this Bureau, and recommend its publication as Bulletin No. 144 of the special series of the Bureau of Plant Industry.

This paper contains the first full account of the apple blotch, which has recently come into prominence as one of the most serious diseases of the southern portion of the apple belt. The life history of the fungus causing the disease has been worked out and the source of the annual infection determined.

It has been conclusively shown by the spraying experiments and demonstrations carried on by the Bureau for the past three years in the Ozarks that the disease can be successfully controlled at a nominal cost, and the results of this work are reported in this paper.

The writers wish to acknowledge their indebtedness to the members of the Benton County (Ark.) Horticultural Society for their hearty cooperation in connection with the field work reported upon in this paper.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—431.

APPLE BLOTCH, A SERIOUS DISEASE OF SOUTHERN ORCHARDS.

INTRODUCTION.

Following the successful treatment of bitter-rot in Virginia in 1905 by the Department of Agriculture, demonstration work for this and other diseases was instituted in the Middle West in the spring of 1906. The demonstrations were primarily intended to show the best methods of controlling the apple scab and bitter-rot, both of which had been reported as very destructive throughout that region in previous years, but as the season progressed it was found that apple blotch was far more destructive than apple scab and bitter-rot combined. The writers, who were in charge of this demonstration work, naturally turned their attention to an investigation of the blotch disease.

The attention of the Department was first called to this disease in 1897, when specimens of it were received from Maryland and Texas. Mr. M. B. Waite photographed the affected fruits and determined the fungus to be a species of Phyllosticta. Since that time specimens of it have been received frequently from various parts of the eastern United States, but in no case was it reported as a serious pest. Upon inquiry, however, it was found that it must have been prevalent to an injurious extent in the Ozarks of Arkansas and Missouri for the past six or seven years. It has been commonly confused with apple scab and the damage done by it attributed to scab, which probably accounts for its serious nature having been overlooked until recently.

The disease is well distributed over the eastern half of the United States, having been recorded at the Department of Agriculture from Alabama, Arkansas, Georgia, Illinois, Kansas, Kentucky, Maryland, Michigan, Missouri, Nebraska, New Jersey, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, and West Virginia, but it reaches the height of destructiveness in the southern portion of the Ozark plateau. In northwestern Arkansas and portions of southern Missouri 75 per cent of the crop is commonly affected, and the disease is almost as bad in portions of southern Illinois. During September, 1906, the writers visited many of the orchards of Benton County, Ark., and found that fully 50 per cent of the fruit in these orchards was rendered unfit for barreling

by this disease. From these observations it was estimated that the loss to the growers in this county alone amounted to $950,000. The disease was even worse in 1907, and although the crop was lighter the higher price of apples made the loss about the same as in the previous year. In 1908 the loss from the disease was immaterial, owing to the failure of the apple crop; however, the few apples that were produced were as badly affected with the disease as were those in the previous two years.

An examination made by one of the writers of orchards at various points in southern Kentucky and in Tennessee, Georgia, and Alabama showed that the disease was very destructive in those localities. Not only was the fruit of susceptible varieties rendered unfit for market, but the trees themselves were badly weakened by the cankers. On account of the disease the growing of several varieties well adapted to the locality has been practically discontinued. In certain sections of Alabama and Georgia the Ben Davis, Red Astrachan, Shockley, and Yates varieties, which formerly did well, have in recent years been almost a complete failure, owing apparently to attacks of this disease.

It appears, therefore, that apple blotch is the most destructive disease of the southern half of the apple belt. Occasionally bitter-rot, as in the year 1900, overshadows all other diseases in destructiveness, but taken year by year apple blotch is more serious. Fortunately the disease is amenable to treatment and can not gain a foothold in well-sprayed orchards. It is not sporadic in its nature and must accumulate on the twigs several years before a serious outbreak on the fruit can occur.

The disease as it appears on the fruit was first reported in 1902 by Clinton,[a] who attributed it to an undescribed species of Phyllosticta. In 1903 it was reported by Faurot[b] as occurring to a serious extent in southern Missouri, and in 1906 Crandall,[c] in connection with his work on liquid versus dust spraying, mentioned a disease which may have been the same thing. Scott and Quaintance,[d] in 1907, gave a detailed description of the disease on the fruit and the results of its successful control by spraying. Later in the same year Rolfs[e] published a description, with recommendations for its treatment.

The relation of twig cankers and leaf-spots to the fruit blotch was first reported by the writers[f] in 1907. Almost simultaneously

[a] Illinois Agricultural Experiment Station, Bulletin 69, pp. 190–192, plate B, fig. 1, a, b, and c.

[b] Missouri State Fruit Experiment Station, Bulletin 6, pp. 7–8.

[c] Illinois Agricultural Experiment Station, Bulletin 106, pp. 217–218.

[d] U. S. Department of Agriculture, Farmers' Bulletin 283, pp. 14–18, fig. 2.

[e] Missouri State Fruit Experiment Station, Bulletin 16, p. 5.

[f] Proceedings of the Benton County (Arkansas) Horticultural Society, August 8, 1907.

Sheldon[a] reported observations which had led him to the same conclusions, and in addition he identified the fungus as *Phyllosticta solitaria* E. & E. Stevens[b] later in the same year recorded the canker form of the disease from several localities in North Carolina.

DESCRIPTION AND BEHAVIOR OF APPLE BLOTCH.

Apple blotch occurs on the fruit, branches, and leaves. Although the form on the fruit is by far the most important from an economic standpoint, the twig cankers play an important part in the life cycle of the fungus causing the disease.

FRUIT BLOTCHES.

The first evidence of the disease on the fruit is a very small, inconspicuous, light brown blotch which under a hand lens has the appearance of a stellate collection of brown fibers just beneath the epidermis. The blotch, spreading radially, increases in size, attaining a diameter of from one-eighth to three-eighths of an inch, sometimes one-half an inch, and becomes darker in color. The advancing margin is irregular and jagged and has a fringed appearance. On very young apples the points of infection occasionally show as small water-soaked areas, and in wet weather there may be a yellowish gummy exudation from the spots. Where the spots are numerous they often coalesce and form large blotches, which may cover half the apple or more. The fungus kills only the superficial cells (the epidermis and outer perenchyma), so that the continued growth of the uninvaded tissues beneath results in a cracking of the diseased areas. The cracks thus formed, though usually about half an inch long, may girdle the fruit and extend to the core. The cracks often intersect, forming a cross. The character of the spots varies somewhat on different varieties. There are all gradations, from those on the Missouri variety, which are quite large, much fringed, and smooth, to those on the Limbertwig, which are small, compact, and often umbonate. An occasional spot somewhat rectangular in shape may be decidedly sunken and quite black, with a definite margin. (See Pl. I, figs. 1 and 2, and Pl. II, fig. 2.)

Within a few days after the spots become visible, black pycnidia begin to develop on the diseased areas. Three or four to many occur on each spot, and they may be scattered promiscuously or grouped on a small blister cracked around the margin.

The general effect of the blotches on the fruit is to mar its appearance and render it unfit for packing. Moderately affected fruit, especially if not badly cracked, may be evaporated, but much of it

[a] Science, n. s., 26, No. 658, pp. 183–185, August 9, 1907.

[b] Science, n. s., 26, No. 673, pp. 724–725, November 22, 1907.

can not be used for this purpose, owing to the difficulty of paring, and is a total loss except where it can be used for vinegar. A large percentage of the affected fruit drops prematurely, and unless utilized immediately becomes a total loss.

TWIG CANKERS.

The fungus attacks fruit spurs, twigs, and rapidly growing shoots, producing characteristic cankers. On fruiting branches these cankers are small and rather inconspicuous, being about one-eighth of an inch wide and one-half an inch or more long. (Pl. I, fig. 4.) They first appear as small purple or blackish blotches. As they increase in size they become brown in the center, retaining a purple margin, but may finally become gray. The bark soon cracks around the cankers, especially along the lateral edges. On rapidly growing shoots, particularly water sprouts, the cankers have the same general appearance as on fruiting branches, but are much larger, often measuring an inch or more in length and sometimes girdling the stem. (Pl. I, fig. 3.) The longitudinal cracks appear not only along the edges but through the cankers, giving them eventually a rough and scurfy appearance. This is especially noticeable on those which are two or three years old. Cankers with spore-bearing pycnidia are first formed on the current year's growth during the summer and fall. The fungus lives over winter in the canker, and during the following spring extends its growth, enlarging the diseased area, and produces new pycnidia on the advancing margin. This growth may continue for several years, as fresh spores have been found on cankers evidently three or four years old. Frequently, however, the canker is cut off from the healthy tissue by cracks, dries up, and later the wound may heal over.

As a rule these cankers do not materially injure the tree, killing only a few small branches and water sprouts, but in the case of some varieties they are so numerous and extend so rapidly that they kill the large branches, and even the main limbs as well. A block of 200 Northwestern Greening trees at Lanagan, Mo., has been practically destroyed by this disease. When visited by the writers in the spring of 1907, the fruiting wood, water shoots, and even larger limbs were almost completely covered with cankers, and many of them were girdled, so that the trees presented a very ragged and sickly appearance. (Pl. II, fig. 1.) So far as the writers have observed, this is the only case in which trees have been killed by the disease, but frequently Missouri, Limbertwig, and Red Astrachan trees become so badly affected that much of the bearing wood is killed and the trees are materially weakened.

In 1906 Mr. H. W. Gipple, of Bentonville, Ark., called the attention of the writers to a disease which often kills a large percentage of

the fruit buds in late summer, especially on Limbertwig, Missouri, and Ben Davis trees, and suggested that possibly the apple-blotch fungus was also responsible for this trouble. An investigation showed that both the apple-blotch fungus and the black-rot fungus (*Sphaeropsis malorum* Peck) were present in the diseased buds. Observations in the orchard and culture work in the laboratory showed that the apple-blotch fungus extended down from diseased leaf petioles into the twigs at the base of the buds, which were soon killed. It was found that Sphaeropsis soon invaded the diseased buds and perhaps assisted in killing them. This trouble begins to show about midsummer and becomes more pronounced as the season advances, sometimes injuring the fruit buds of a few varieties to such an extent that the crop the following year is almost a failure.

During 1907 a similar diseased condition of Winesap buds was found to be common in Arkansas and Missouri. As this variety is practically immune from the Phyllosticta disease, some doubt was thrown on the conclusion given above. Cultures from these diseased Winesap buds nearly always developed *Sphaeropsis malorum*, but failed to show the presence of Phyllosticta. It would seem, therefore, that at least in the case of the Winesap the black-rot fungus is capable of killing the buds without the aid of the apple-blotch fungus. However, a further investigation of the cause of this trouble is desirable.

LEAF SPOTS.

The spots on the leaves caused by the apple-blotch fungus are irregular, light brown, yellowish, or whitish, and quite small, measuring one-sixteenth inch or less in diameter. Each spot bears one to several small black pycnidia. These diseased areas are scattered promiscuously over the surface of the leaf, and frequently occur on the veins, midrib, and petiole. (Pl. I, fig. 5.) They are so minute that several dozen may occur on a leaf without attracting attention and perhaps without material injury, but in severe cases they become conspicuous by their numbers, several hundred frequently occurring on a single leaf. The badly affected leaves may drop prematurely or die and turn brown on the tree. The latter condition results from a girdling of the petiole by the fungus, and often in midsummer such susceptible varieties as the Missouri and Limbertwig show tufts of brown leaves involving half or more of the foliage. This results in a weakening, and in many cases the death, of the fruit buds for the following year's crop. However, as a leaf-spot disease it is of comparatively minor importance, the common leaf-spot being caused by *Sphaeropsis malorum* Peck, which produces much larger spots.

INFECTION PERIODS.

The twig cankers in which the apple-blotch fungus passes the winter are undoubtedly the chief source of infection. During the warm, moist weather of spring the fungus resumes activity and soon begins to produce spores, which ooze from the pycnidia in enormous quantities. These are readily carried by rain and other agents to the young fruits, twigs, and leaves, producing the first spring outbreak of the disease. According to observations made by the writers in the Ozarks during the past three years, infections begin to take place from four to five weeks after the petals have fallen, and the blotches on the fruit appear about three weeks later. In 1906 the apple petals were off by April 29, and the first spots on the fruit were observed on June 26, two months later, while in 1907 the petals were shed by March 31, a month earlier than the previous year, and the first blotches were seen on May 31. Although the most extensive outbreak occurs at this early period, infections continue to take place throughout the season, young spots being commonly found on the fruit up to picking time.

As is the case with other fungous diseases, outbreaks of apple blotch are more or less dependent upon weather conditions, although, unlike bitter-rot, it develops in cool as well as in warm weather. Rains or heavy dews are necessary for the germination of the spores and the spread of the fungus from the twigs to the fruit.

SUSCEPTIBILITY OF VARIETIES.

There is a great range in the susceptibility of different varieties to apple blotch, some being almost immune, while others under the same conditions become badly affected. Of the commercial varieties grown in the Ozarks, the Ben Davis, Missouri, and Limbertwig are most subject to the disease, the entire crop of these, especially in old unsprayed orchards, often being destroyed. The disease is equally bad on other varieties, such as the Northwestern Greening, Smith, and Maiden Blush. On the other hand, the Winesap, Jonathan, York Imperial, and some others, are almost immune.

The following is a list of varieties, given in the order of their susceptibility to the attacks of this disease. As this list is based solely upon observations made by the writers during 1906 and 1907, mostly in the Middle West, the arrangement is more or less tentative and will probably have to be changed somewhat when further studies are made:

Badly affected.—Northwestern Greening, Missouri, Ben Davis, Limbertwig, Red Astrachan, Smith, Maiden Blush, Lawver, Shockley, Clayton, Willow, Arkansas Black, and Gano.

Moderately affected.—Oldenburg, Benoni, Arkansas, Bradford, Ingram, Collins, Minkler, Rambo, and Golden Russet.

Slightly or not at all affected.—Grimes, Winesap, Jonathan, York Imperial, and Red Reese.

In addition to those mentioned in the above list the writers have observed the blotch in various sections on the following varieties: Sherman, Shannon, Arkansas Pippin, Bough, Baldwin, White Pearmain, Yellow Newtown, Smokehouse, and Northern Spy; also on the wild crab apple (*Pirus coronaria*) in Pennsylvania.

CAUSE OF THE DISEASE.

The apple-blotch disease is caused by a fungus belonging to the genus Phyllosticta. Clinton,[a] in 1902, after having submitted specimens of this fungus to both Ellis and Peck, concluded that it was a new species. However, in 1907 Sheldon[a] identified it as *Phyllosticta solitaria* E. & E., which was described in 1895[b] on leaves of the wild crab apple (*Pirus coronaria* L.). Sheldon did not examine the type specimens, but found that the spores of the apple-blotch fungus, on the wild crab as well as on the common apple, agreed with Ellis and Everhart's description.

Through the kindness of Dr. W. A. Murrill, assistant director of the New York Botanical Gardens, the writers were able to examine the type collection of *Phyllosticta solitaria*, and found that the spores were practically identical with those of the apple-blotch fungus (Pl. III, fig. 5) and that the spots on the leaves were of the same character as those described above on the leaves of the common apple.

LIFE HISTORY OF THE FUNGUS.

In 1906, when the writers first began to study the apple-blotch disease, very little was known of the fungus causing it. It was supposed that this fungus lived over winter in the fruits mummified by the disease and that these mummies furnished the source of infection for the new crop. An examination of a large number of such diseased fruits revealed so few spores that they could not be considered an important source of infection. The fungus evidently does live over winter in the mummied fruits and in the spring makes an abortive attempt to produce either perithecia or pycnidia, but as yet no ascospores and but few pycnospores have been obtained from this source. It was necessary, therefore, to look elsewhere for the source of spring infection.

[a] Loc. cit.

[b] Ellis and Everhart, Proceedings of Academy of Natural Sciences of Philadelphia, 1895, p. 430.

In September, 1906, the writers found apple-twig cankers caused by a fungus which appeared to be the same as the apple-blotch fungus. The fungus from these twig cankers and that from the spots on the fruit grown in the same kind of medium under the same conditions were so similar in all respects that one could not be distinguished from the other. Moreover, spores from both agreed in color, shape, and size. It seemed evident, therefore, that the two diseases were caused by the same fungus. For like reasons it was suspected that the fungus causing the leaf spots and petiole cankers found associated with the twig cankers was also the same. (Pl. III, figs. 2, 3, and 4.) Definite proof of this was obtained by inoculation experiments made in the following year.

In the spring of 1907 at the time the first fruit infections were taking place spores were found oozing in great quantities from pycnidia on the twig cankers, strongly indicating that these cankers formed the principal source of infection for the first outbreak on the fruit.

Under favorable conditions the spores which are carried from the cankers to the young fruits, twigs, and leaves may germinate in fifteen hours, giving rise to one or two germ tubes, which soon penetrate the epidermis and form a much-branched mycelium. In the fruit the growth of the fungus is slow and restricted to a few layers of cells just beneath the skin. The mycelium spreads out from the point of infection in a somewhat stellate manner; the invaded tissues turn brown, producing the characteristic blotches as seen on the surface. In a short time the fungus begins to produce pycnidia, or small receptacles in which spores are borne. (See Pl. III, fig. 1.) These pycnidia develop beneath the epidermis and appear as small, black, raised points. When mature, they rupture the epidermis and emit the spores, which are abjointed from short sporophores, through a small opening called an ostiolum.

The spores are ovoid to elliptical ovoid, hyaline, unicellular, and measure 8 to 10 by 5.5 to 6.5 μ. They are enveloped in a gelatinous sheath, which is frequently prolonged at the apical end into a thread-like appendage. (See Pl. III, fig. 4.) These appendages are as a rule rather inconspicuous, usually difficult to discern on spores from dried material, but readily seen on those that have just reached maturity. They vary in length, but are generally about twice as long as the spore. They are apparently of the same nature as the appendages which occur on the conidia of *Guignardia vaccinii* Shear and *G. bidwellii* (Ell.) V. & R. as described by Shear.[a] The writers have

[a] U. S. Department of Agriculture, Bureau of Plant Industry, Bulletin 110, p. 15, 1907.

observed similar appendages on the spores of *Phyllosticta minima* (B. & C.) E. & E., the fungus which causes the common maple leaf-spot.

The pycnospores, which are produced in great abundance on young green fruits until nearly midsummer, germinate readily and under favorable conditions may reinfect the fruits, twigs, and leaves. As the fruit approaches maturity spore production ceases, although pycnidia-like bodies continue to be formed. It is possible that this is an attempt on the part of the fungus to produce an ascigerous stage, but an examination of a great quantity of diseased fruits both in the fall and in the following spring has failed to reveal any asci. The conceptacles are filled with irregular cell-like bodies rich in protoplasm, which may be abortive asci.

The growth of the fungus on the twigs is confined to the bark, where it kills the tissues and forms the cankers previously described. The formation of pycnidia begins soon after the cankers are visible and continues throughout the season as the cankers increase in size. These pycnidia produce spores in great abundance which are similar in all respects to those from the fruit and, like them, as shown by inoculation experiments, may infect fruit and leaves. The fungus is perennial in the cankers, enlarging the diseased areas from year to year.

CULTURAL CHARACTERS.

The fungus grows well on nearly all ordinary culture media, such as potato, apple, prune, and corn-meal agar, sterilized potato cylinders, beans, rice, corn meal, and apple twigs. On agar the vegetative growth is quite characteristic, producing an irregular dark gray mass of mycelium, which in its compact radiating appearance suggests the blotches on the fruit. (Pl. III, fig. 10.) The fungous growth is very dense but quite restricted. The mycelium is for the most part embedded in the agar and is greenish black, but the fungous mass has a grayish appearance on account of tufts of short, hyaline hyphæ, which are produced over the surface. On apple wood, rice, and corn meal the growth is more extensive and less compact than on agar.

The mycelium is made up of profusely branched, anastimosing, septate, thick-walled hyphæ about 2.5 μ in diameter. (See Pl. III, fig. 9.)

The fungus does not fruit freely on culture media, and so far the writers have been able to secure spore-bearing pycnidia only on sterilized apple wood and corn-meal agar. Pycnidia-like bodies are formed in great abundance on all media, but these are for the most part sterile. In apple-wood cultures the fungus generally fruits well, producing little groups of pycnidia rich in spores.

INOCULATION EXPERIMENTS.

To show that the fungus which causes the twig cankers is also the cause of the fruit blotch, a series of cross-inoculations was undertaken during the season of 1907. Owing to the press of other work the writers were unable to devote much time to these experiments, so that the results are not all that could be desired. The first inoculations were made on June 26, after the main natural infection period had passed and dry weather had set in.

As spores could not be obtained in sufficient quantities from the pure cultures then on hand, fertile pycnidia were carefully picked from thoroughly washed young cankers on the twigs and crushed in sterile water, thus liberating the spores. An examination of drops of this liquid showed that it was rich in spores of the canker fungus, and cultures made from it proved to be free from other fungi, but, as might be expected, were slightly contaminated with bacteria. This fluid, containing spores from young cankers, was applied with an atomizer to the fruit and foliage of a Ben Davis tree in a young orchard just beginning to bear, in which the disease had not yet gained a foothold. The fruit and foliage of another tree in the same orchard were sprayed with sterilized water containing spores obtained in a similar manner from pycnidia on the fruit. A third tree was sprayed with sterile water as a check. Although this experiment was made in a period of dry weather, the effects of the inoculation began to show in about a month. On July 24 numerous small blotches were found on the fruits which had been inoculated with the canker spores, as well as on those inoculated with the fruit-blotch spores. The characteristic spots on leaf blade and petiole were also found on both trees. A careful examination of the check tree, as well as of a number of others in the same orchard, revealed no such blotches or leaf spots. As the season advanced the blotches increased in size, and when the crop was picked on September 3, the following data were obtained:

Tree 1, inoculated with canker spores, gave 34 apples affected with a total of 114 blotches and 52 sound apples. Many of these latter were not inoculated because they were in the top of the tree and could not be reached with the atomizer. (See Pl. IV, figs. 1 and 2.)

Tree 2, inoculated with spores from the fruit blotches, gave 14 apples affected with a total of 97 blotches and 4 sound apples.

Tree 3, check, gave a total of 59 apples, only one of which was affected, and that with only one blotch. Another adjacent tree bore 61 apples, none of which were affected.

No cankers were found on the twigs of either inoculated tree, owing perhaps to the hardened condition of the bark brought about by the

dry weather. However, the writers have not yet determined the conditions necessary for twig infection.

PREVENTIVE MEASURES.

The experiments and demonstrations conducted by the writers in 1906 show that the apple-blotch disease may be controlled by proper applications of Bordeaux mixture,[a] and these results were confirmed by similar work in 1907. In order to determine the number of applications required and the time at which they should be made the following experiments were carried out at Bentonville and Gravette, Ark.:

SPRAYING EXPERIMENTS AT BENTONVILLE, ARK.

In the orchard of Mrs. Sneed, at Bentonville, a block of eighteen-year-old Ben Davis trees which were badly affected with the disease the previous year and which are said to have never been sprayed before was divided into seven plots of six trees each and sprayed with Bordeaux mixture. Twelve trees were selected as checks and left untreated. The crop, including windfalls, from three trees in each plot and from six check trees was sorted with reference to blotch into diseased and sound fruit and the apples in each class counted. The treatment given and the results from each plot are presented in Table I.

TABLE I.—*Results of experiments for the control of apple blotch on Ben Davis trees, Bentonville, Ark., 1907.*

Plot numbers (3 trees of each plot).	Treatment with Bordeaux mixture (5–5–50 formula).				Fruit picked September 12 to 19.		
					Sound fruit.	Blotched fruit.	
					Number.	*Number.*	*Per cent.*
1	Apr. 27	May 22	June 15	July 5	4,056	208	4.9
2	Apr. 27	May 22	June 15	.....	3,008	115	3.7
3	Apr. 27	May 22	.....	.....	4,292	606	12.5
4	Apr. 27	.....	June 15	July 5	4,837	595	11.0
5	.....	May 22	June 15	July 5	1,242	2,705	68.5
6	.....	.....	June 15	July 5	2,169	4,237	66.1
7	.....	.....	.....	July 5	1,403	3,346	70.5
8, check (6 trees), no treatment	.....	.....	.....	.....	1,103	10,235	90.3

In studying this table it should be remembered that the season was a month earlier than normal and that April 27, the date of the first application, corresponds to about May 27 of the previous year, both dates being respectively about a month after the petals had fallen. Moreover, it should be borne in mind that the weather turned dry about the middle of June, after which the rainfall was very light, so

[a] U. S. Department of Agriculture, Farmers' Bulletin 283, pp. 17–18.

that but few infections took place during the remainder of the season. The last two applications, made on June 15 and July 5, were therefore of little value in the control of the disease; but during a season of ordinary rainfall infections take place throughout the season, making late spraying necessary for proper protection, as was demonstrated in the previous year's work.

The most striking feature of this experiment, as shown in the table, is the effect of the first application, made thirty days after the petals fell. The disease was successfully controlled in all the plots which received this application, while more than half the crop of the plots on which it was omitted was affected. This will be clearly seen by comparing the results from Plots 2 and 5, both of which received three applications, the only difference being that the treatment of the latter was not begun until three weeks after that of the former. The crop of Plot 2 shows only 3.7 per cent of diseased fruit, while 68.5 per cent of that on Plot 5 was affected. Plots 3 and 6 may be similarly compared. The crop of the check trees was almost wholly destroyed by the disease, 90.3 per cent of the fruit being affected. This, when compared with Plots 1 and 2, in which less than 5 per cent of the crop was diseased, shows very strikingly the good results from timely applications of Bordeaux mixture. (Pl. V, figs. 1 and 2.)

This experiment was practically duplicated on a block of Limbertwigs in the same orchard, and the results are given in Table II, which follows.

TABLE II.—*Results of experiments for the control of apple blotch on Limbertwig trees, Bentonville, Ark., 1907.*

Plot numbers (2 trees of each plot.)	Treatment with Bordeaux mixture (5-5-50 formula).				Fruit picked October 5 to 10.		
					Sound fruit.	Blotched fruit.	
					Number.	*Number.*	*Per cent.*
1	Apr. 27	May 22	June 15	July 5	4,233	360	7.8
2	Apr. 27	May 22	June 15	.....	7,170	386	5.1
3	Apr. 27	May 22	.....	.....	4,256	305	6.7
4	Apr. 27	.....	June 15	July 5	6,824	646	8.6
5	.....	May 22	June 15	July 5	3,115	6,515	67.7
6, check (4 trees), no treatment.	.....	.....	.....	.....	3,158	17,688	84.9

The results on the Limbertwig trees, as shown in this table, were about the same as those obtained on the trees of the Ben Davis variety. Again the importance of the first application, April 27, is emphasized, the disease being controlled on all plots receiving this treatment. Plot 2, which received three applications, beginning on April 27, had only 5.1 per cent of the crop affected, while Plot 5, which received the same number of treatments, though beginning three weeks

later, had 67.7 per cent of the crop affected. (Pl. VI, figs. 1 and 2.) This emphasizes the fact that in order to control the disease the treatment must be given before infections take place.

SPRAYING EXPERIMENTS AT GRAVETTE, ARK.

At Gravette, Ark., in the orchard of Mr. P. A. Rodgers, a combined experiment and demonstration was conducted. A block of 120 large Ben Davis trees was divided into 5 plots of from 12 to 40 trees each. Plots 3 and 4 constituting a demonstration of 60 trees. Plots 1 and 2, from which poor results were expected, were limited to a dozen trees each, and Plot 5, the check, consisted of 12 trees. Early in the season 3 average trees in each plot were selected and at picking time the crop, including all windfalls, was sorted and counted. The results are given in the following table.

TABLE III.—*Treatment and results in apple-blotch experiments, Rodgers orchard, Gravette, Ark., 1907.*

Plot numbers (3 trees of each plot).	Treatment with Bordeaux mixture (5-5-50 formula).						Fruit picked September 23 to 26.		
							Sound fruit.	Blotched fruit.	
							Number.	*Number.*	*Per ct.*
1	Apr. 4			June 5	July 5	Aug. 6	1,625	1,156	41.6
2	Apr. 4	Apr. 11		June 5	July 5	Aug. 6	4,769	2,343	32.9
3	Apr. 4	Apr. 11	May 2	June 5	July 5	Aug. 6	5,282	432	7.6
4	Apr. 4		May 2	June 5	July 5	Aug. 6	5,093	393	7.1
5, check (6 trees), no treatment.							3,733	4,632	55.4

The results here confirm those obtained in the Bentonville orchard, and show that the application made on May 2, just before infection began, was more important in the control of apple blotch than all the others combined. Plot 4, which was sprayed according to the demonstration schedule, had only 7.1 per cent of the fruit affected with the disease, while 32.9 per cent of the fruit was diseased on Plot 2, which had the same treatment, except that the second application was made on April 11, a week after the petals fell, instead of on May 2, three weeks later.

In the spraying demonstrations conducted in 1907 the disease was as thoroughly controlled as in the previous year. At Gravette, in the orchard of Mr. J. T. Oswald, a block of 125 very large Ben Davis trees was sprayed April 7, May 3, June 6, July 6, and August 7, five applications in all. Twenty trees were left unsprayed as checks. The fruit from 9 average trees of the sprayed block was sorted and counted and 95.4 per cent found to be free from blotch, while a count of 3 check trees showed only 34 per cent of the fruit free from the

disease. The results of the demonstration in the Rodgers orchard are shown in Table III, of which Plot 4 was given the demonstration treatment. The sprayed block yielded 92.9 per cent of sound fruit, and the checks only 44.6 per cent.

The spraying not only protects the fruit but the twigs as well, thus preventing the formation of cankers, the chief source of infection for the fruit. The value of one season's treatment in this connection was shown in experiments conducted in the orchard of Mr. H. W. Gipple, at Bentonville, Ark. Trees left unsprayed in 1906 and 1907 had 64.6 per cent of the 1907 crop affected with the disease, while trees sprayed in 1906, but left unsprayed in 1907, had only 27 per cent of diseased fruit. As shown by an examination of the trees, very few new cankers were formed on the trees sprayed in 1906, which undoubtedly accounts for the smaller amount of fruit infection in 1907. It would seem, therefore, that a few years' thorough spraying might exterminate the disease from an orchard.

STRENGTH OF BORDEAUX MIXTURE FOR APPLE BLOTCH.

In the experiments reported in this paper Bordeaux mixture composed of 5 pounds of bluestone and 5 pounds of lime to 50 gallons of water was used. In several other experiments conducted by the writers various strengths were used, and it was always found that the weaker mixtures were uniformly less effective against both apple blotch and bitter-rot. However, the mixture containing 4 pounds of bluestone controlled these diseases almost as well as the stronger one and has the advantage of being slightly less injurious to the fruit and foliage. It also developed from these experiments that an excess of lime in the Bordeaux mixture was slightly advantageous in respect to injury, the 4–4–50 mixture causing somewhat more injury than the 4–6–50 mixture. All things considered, the following formula is perhaps best for general use:

4 pounds of bluestone.
4 to 6 pounds of stone lime.
50 gallons of water.

To this should be added 2 pounds of arsenate of lead or 6 ounces of Paris green for the control of the codling moth and other insects. If a good lime which will entirely slake into a smooth paste is used, 4 pounds are sufficient, but if the lime is poor or partially air-slaked 5 or 6 pounds, or even more, may be required to get the least possible injury.

The usual directions for preparing Bordeaux mixture by dissolving the bluestone in one vessel, slaking the lime in another, and diluting each with half the required quantity of water before pouring them

together through a strainer into the spray tank should be followed. For extensive operations an elevated platform large enough to accommodate the necessary barrels and tanks and high enough to allow the two diluted solutions to run by gravity into the spray tank or into a supply tank is almost indispensable. To facilitate the preparation of the mixture in large quantities stock solutions of bluestone and lime should be made.[a]

Most of the spraying was done with a gasoline power outfit, such as is shown in Plate IV, figure 3, although a hand outfit of the 50-gallon barrel type was used in a part of the work. The power machine was equipped with two 35-foot leads of discharge hose for the operators working from the ground and one shorter length (about 15 feet) for the use of the man in the tower spraying the tops of the trees. Each lead of hose was attached to a 10-foot bamboo spray rod fitted with a double Vermorel nozzle deflected so as to direct the spray inward and downward.

RECOMMENDATIONS FOR THE CONTROL OF APPLE BLOTCH.

As the principal infection period comes from four to six weeks after the petals have fallen, it is necessary for the control of this disease to have the fruit protected at this time, and as scattering infections continue to take place throughout the season a coating of the fungicide must be maintained until picking time. The number of applications necessary to afford this protection will depend upon the season, wet weather naturally requiring more than dry.

Ordinarily four applications of Bordeaux mixture will control the disease: The first, three to four weeks after the petals have fallen, which corresponds to the second application in the treatment of the codling moth; the second, about four weeks later, and the third and fourth at intervals of three weeks thereafter. The second and succeeding applications correspond with the treatment for bitter-rot, so that one course of treatment will control both diseases. While the disease can be readily controlled by the proper methods, very careful and thorough work is required.

A few days' delay in making the first application may result in an entire failure, and unless all the fruit is reached and well sprayed only partial success may be expected. The inner and higher portions of the trees, which in practice are often missed, should be thoroughly sprayed, as well as the outer and lower portions.

Neglect of pruning is conducive to the development of the disease. The fungus accumulates on the numerous twigs, branches, and water

[a] For fuller information regarding the preparation of spraying mixtures, see U. S. Department of Agriculture, Farmers' Bulletins Nos. 243 and 283.

sprouts of unpruned trees, and these are an ever present source of infection for the fruit. Careful pruning will not only remove a large portion of the diseased twigs but will greatly facilitate thorough spraying.

COMBINATION TREATMENT FOR APPLE BLOTCH AND OTHER DISEASES.[a]

The treatment for apple blotch conforms closely to that for apple bitter-rot and with one or two additional applications all the other important fruit and leaf troubles may be controlled. The following course of treatment is therefore recommended for orchards in southern sections, especially where apple blotch and bitter-rot occur.

First application.—When the cluster buds are well out, just before the blossoms open. This is the first treatment for apple scab and is of special importance for badly scabbing varieties, such as the Winesap, Arkansas, Arkansas Black, and Red June. It may be omitted from the Ben Davis, Gano, Jonathan, and York Imperial, which scab very little or not at all in most southern sections. This application also constitutes the treatment for the spring canker worm.

Second application.—Immediately after the petals fall. The work may be commenced when about two-thirds of the petals have dropped and should be finished within a week or ten days, that is, before the calyx lobes close. This constitutes the second application for scab and the first for the codling moth and is the most important treatment for both.

Third application.—Three to four weeks after the petals have fallen. This is the first and most important application for apple blotch and is the second treatment for the codling moth.

Fourth application.—Eight to nine weeks after the petals have fallen, or not later than June 25. This is the first treatment for bitter-rot, the second for blotch, and the third for the codling moth.

Fifth application.—Two to three weeks after the fourth application. This is the second treatment for bitter-rot, the third for blotch, and is also important for the codling moth.

Sixth application.—Three weeks after the fifth application. This is the last treatment for bitter-rot and blotch and is important to prevent late infections. It is also very important for the control of the second brood of the codling moth.

The course of treatment given above is intended for the control of all the important apple troubles, such as scab, bitter-rot, blotch, leaf-spot, codling moth, and canker worm, and does not apply to all

[a] Mr. A. L. Quaintance, of the Bureau of Entomology, is the authority for that portion of this schedule of treatments relating to the codling moth.

varieties alike. For example, the Winesap, which scabs badly but is not susceptible to bitter-rot and blotch, should be given the first three applications, but need be sprayed thereafter only for the codling moth, using the arsenical alone. On the other hand, in the treatment of the Ben Davis, which does not scab in the South but is very susceptible to apple blotch and sometimes rots badly, the first application may be omitted except in restricted localities where the spring canker worm is a pest; and in the second application the formula may be reduced to 2 or 3 pounds of bluestone and 3 or 4 pounds of lime to 50 gallons of water in order to reduce the Bordeaux injury as much as possible.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) Apple blotch on fruits, twigs, and leaf. 1.—A mature Ben Davis apple affected with blotch, showing the general character of the blotches and the cracking of the fruit caused by the disease. 2.—Two Ben Davis apples about one-third grown, showing the disease as it appears on badly infected fruit about six weeks after infection. 3.—Portion of a water sprout from a Limbertwig tree, showing cankers in different stages of development. 4.—Twig of bearing wood from a Ben Davis tree, showing numerous cankers on and near the fruit spurs. 5.—A leaf from a Missouri tree, showing leaf spots and petiole cankers caused by the apple-blotch fungus.

PLATE II. Fig. 1.—View of a Northwestern Greening orchard in which the trees have been practically killed by apple-blotch cankers on the small shoots and larger limbs. Fig. 2.—Six Ben Davis apples about one-third grown badly affected with blotch.

PLATE III. Microscopic and cultural characters of the apple-blotch fungus. 1.—A vertical section of a single pycnidium from a spot on a Ben Davis apple, showing pycnospores in various stages of development × 185. 2, 3, 4, and 5.—Mature pycnospores of the apple-blotch fungus from various sources, showing appendages × 700. (2) From leaf spot on Missouri apple leaf; (3) from canker on Limbertwig water sprout; (4) from blotch on Ben Davis apple; (5) from type specimen of *Phyllosticta solitaria* E. & E., on leaf of *Pyrus coronaria*. 6, 7, and 8.—Germinating spores × 700. (6) In potato agar; (7) in apple agar, twenty-two hours after sowing; (8) same spore as figure 7, seventy-eight hours after sowing. 9.—Mycelium of apple-blotch fungus from corn-meal agar culture × 370. 10.—Two colonies of the apple-blotch fungus one month old growing in apple agar.

PLATE IV. Fig. 1.—A Ben Davis apple, showing blotches produced by inoculation with spores from twig cankers. Fig. 2.—A Gano apple, showing blotches resulting from natural infection. Fig. 3.—A power spraying outfit in operation.

PLATE V. Fig. 1.—Entire crop of apples from a Ben Davis tree sprayed three times, beginning at the right period for the control of the disease. The apples in the basket, 3.75 per cent of the crop, are the only ones affected with the disease. Fig. 2.—Entire crop from an unsprayed Ben Davis tree in the same orchard as the apples shown in figure 1. The apples in the pile, 94.36 per cent of the crop, are all affected with blotch.

PLATE VI. Fig. 1.—Entire crop of apples from a Limbertwig tree sprayed three times, beginning at the right period. The apples in the basket, 5.1 per cent of the crop, are the only ones affected with blotch. Fig. 2.—Entire crop from a Limbertwig tree in the same orchard as the apples shown in figure 1 sprayed three times, but the first application made too late. All the apples in the right hand pile, 67.7 per cent of the crop, are affected with blotch.

FIG. 1.—ORCHARD OF NORTHWESTERN GREENING APPLE TREES ALMOST DESTROYED BY APPLE BLOTCH.

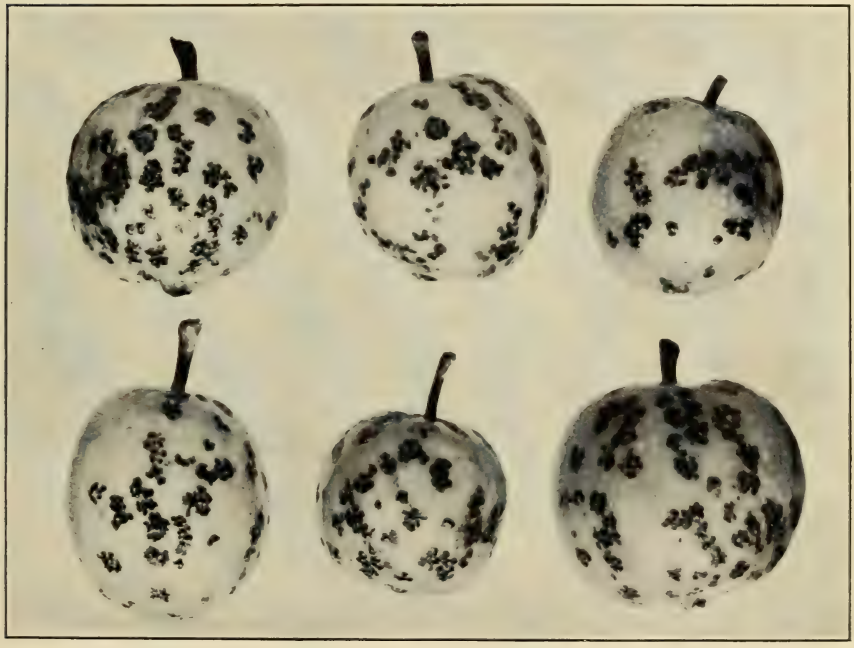
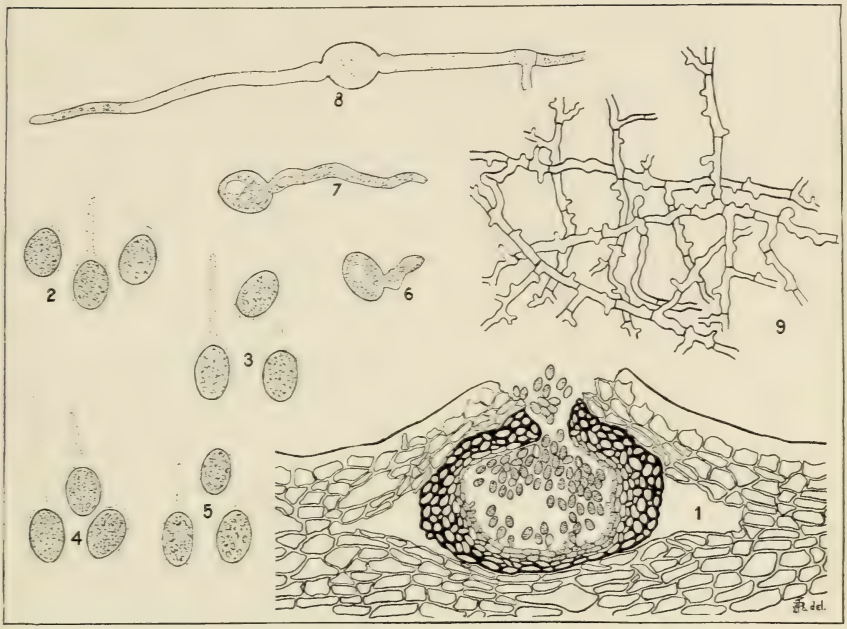


FIG. 2.—SIX BEN DAVIS APPLES, SHOWING THE CHARACTER OF THE DISEASE ON YOUNG FRUIT.



MICROSCOPIC AND CULTURAL CHARACTERS OF THE APPLE-BLOTCH FUNGUS.

FIG. 1.—A BEN DAVIS APPLE, SHOWING BLOTCHES PRODUCED BY INOCULATION.

FIG. 2.—A GANO APPLE, SHOWING BLOTCHES RESULTING FROM NATURAL INFECTION.

FIG. 3.—A POWER SPRAYING OUTFIT IN OPERATION.

FIG. 1.—CROP OF BEN DAVIS APPLES FROM A PROPERLY SPRAYED TREE. SOUND FRUIT IN PILE.

FIG. 2.—CROP OF BEN DAVIS APPLES FROM AN UNSPRAYED TREE. BLOTCHED FRUIT IN PILE.

FIG. 1.—CROP OF LIMBERTWIG APPLES FROM A TREE SPRAYED THREE TIMES, BEGINNING AT THE RIGHT PERIOD. SOUND FRUIT IN PILE.

FIG. 2.—CROP OF LIMBERTWIG APPLES FROM A TREE SPRAYED THREE TIMES, BEGINNING TOO LATE. SOUND FRUIT ON LEFT.

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